JAN 7 1921

Subscription Price:
United States and Canada, $6.00 Per Year.

Great Britain, 30 Shillings; Single Copies, 4 Shillings.
Foreign, $6.00 Per Year; Single Copies, 75 Cents.

VOLUME II JANUARY, 1921 NUMBER 9

JAN 5 1921

THE JOURNAL OF INDUSTRIAL HYGIENE

AND ABSTRACT OF THE LITERATURE

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HONORARY CONSULTING EDITOR
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Employment and the Distribution of Industries in their Relation to the Growth and Physical Development of the Young Wage Earner

The Effect of the Inhalation of Gases

Industrial Tuberculosis and the Control of the Factory Dust Problem

Estimation of Toxic Water Soluble Dust with the Palmer Apparatus

Published Monthly at 1 Divinity Avenue, Cambridge 38, Boston, Massachusetts
by Harvard University Press

Great Britain: Macmillan and Co., Ltd., St. Martin's Street, London, W.C. 2

Entered as second-class matter, at the Post Office at Boston, Mass., under Act of March 3, 1879. Published monthly.
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PUBLISHED MONTHLY

VOLUME II JANUARY, 1921 NUMBER 9

EMPLOYMENT AND THE DISTRIBUTION OF INDUSTRIES IN THEIR RELATION TO THE GROWTH AND PHYSICAL DEVELOPMENT OF THE YOUNG WAGE EARNER *

HARRY J. WILSON, O.B.E.

H. M. Superintending Inspector of Factories for Scotland

DURING a period extending over twenty-seven years spent as an inspector of factories in various parts of England and Scotland I have throughout been constantly impressed with the variation in physique of the industrial population. From the beginning I was struck with the obvious stunting in growth and the prevalence of marked deformities, usually due to rickets, in the larger industrial towns, and, on the other hand, equally impressed with the fine, well-set-up workers employed in outdoor occupations, and living in rural surroundings. This contrast in physique was noticeable in men and women alike. At first I was inclined to attribute the disparity in growth to the nature of the employment, but on measuring and weighing numbers of adolescents employed in textile factories in a large town, and an equal number similarly occupied in a country district within the same county, I found that, though there was marked deviation from the normal in the case of the city young people, the country workers were rather above the average in both height and weight. As in both cases the conditions of employment were identical, the hours exactly similar, I was satisfied that the causes of degeneracy lay outside occupation almost altogether, and were obviously related in some way to home conditions. These were utterly different in the cases under review; the country young people lived in good cottage homes, had every appearance of being well fed and looked after, whereas the city workers were drawn from one or two-roomed, squalid tenement houses in a congested area of a manufacturing town, and bore evidence of neglect in their clothing and general appearance. Subsequent investigations have all tended to confirm this impression.

The subject is not, however, so simple as it at first sight appears, for the following reasons. Occupation has a selective effect on its recruits; the delicate, the weakly, the deformed — all, in fact, who are conscious of some physical handicap drift into such callings as make small demand on bodily strength or endurance. Thus, a large proportion of lame, weakly, and ill-developed persons will be found in sedentary occupations or light work. On the other hand,

* An address delivered at the Congress of the Royal Institute of Public Health held in Brussels May, 1920. Received for publication Aug. 23, 1920.

employment which is exacting in its demand on physical fitness and endurance finds recruits among the strong, robust and enterprising young people. No man, for instance, could long follow the calling of a miner unless he was physically fit. At first sight, therefore, it might be argued that the light indoor occupations had an injurious effect on the health and growth of the persons engaged in them, judging by the appearance of the workers and, similarly, that heavy trades — that is, iron and steel manufacture, mining, navvy work, etc. — were necessarily advantageous, inasmuch as the employees appeared physically excellent.

Without doubt, practically every type of occupation, if persisted in long enough, has some definite effect on health; but, confining ourselves for the present to the question of growth, it is obvious that industrial employment can affect it but little if the worker commences wage earning in any particular industry when he is almost full-grown. The very important period is from infancy to 16 or 17 years of age. Among the industries which require sterling health and muscular strength I would place blast furnaces, the laboring departments of iron and steel rolling mills, the heavy chemical trades, cane-sugar refining, and navvy work, and these the employee usually enters over the age of 18, in many cases over 20. It is found that these trades draw their workers largely from agricultural districts; in other words, the men have been born and reared in rural areas and have attained good height and development before taking up industrial work at all.

Home conditions, which I hope to prove are the determining factors in influencing growth and even health in the young, are largely, but not entirely, dependent on the parents' wage. The wages hitherto paid in rural districts have been considerably lower than those prevailing in towns, yet notwithstanding the small remuneration, country parents appear able to rear families which in stature and weight approach closely the physique of the most favored classes, and easily outstrip those of urban origin. This superiority of physique, in spite of low wages, is partially explained by the fact that the rural children are constantly in the open air and benefit by sunshine; there is generally a garden attached to the home which produces vegetables and some fruits; and if the parent maintains a cow and poultry the children are assured of the essential foods which, though easily procurable in country districts, are costly to purchase in towns. These advantages, then, the rural wage earner possesses over his colleague in the city, and they are of infinitely more value than is generally recognized.

In industrial centers, however, the wage is a predominant factor, determining among other things the locality the worker must live in, and the size of the house. The unskilled town laborer is as a rule the worst housed, and in my experience his children are the poorest in physique among all the families of the industrial classes. It is seldom that an unskilled laborer can afford to put his sons to any trade; their maintenance during apprenticeship is too costly. Consequently the sons of laborers tend to become laborers, they take up work which promises high pay in early youth, but as most such jobs are "dead end" in character, the men come on the market again later as general laborers. The position, then, of the unskilled town laborers in the past has been rather a hopeless one and it is not surprising to find the standard of health and physique low in their class. Confirmatory evidence of this is found again and again throughout the recently published report on the physical examination of men of military age by the National Service Medical Boards, 1917 to 1918. Thus, the average height of 230 Glasgow laborers examined for army purposes was 5 feet 2

inches and the weight 8 stone 12, the lowest of any occupational class brought under review. The figures show a deplorably low standard and are a severe reflection on the conditions under which the recruits were reared. In contrast to these and as showing the physical superiority of the country-bred man, the average height of 440 navvies measured by myself, all brought up in agricultural work, was 5 feet 8.8. inches (175 cm.), and the weight 12 stone 4 pounds (78 kg.). The heaviest of these men were from County Kerry; the tallest were natives of the North of Scotland. An inquiry I made into the diet of these rural workers proved that it was exceedingly simple in character, consisting largely of potatoes, oatmeal, milk, and cheese, with very little flesh food.

The stunting of height and undevelopment which is apparent enough during adolescence among poorer paid workers in industrial centers shows itself as a rule before the young person leaves school. The medical inspection of schoolchildren reveals this clearly enough, the deviation from the standard observable at 5 years of age becoming more marked as the child grows older, and at 13 years of age there is, in the case of Glasgow board schoolchildren, a difference of nearly 5 inches in height between them and corresponding young people in the North of Scotland, and a difference of almost 20 pounds in weight. Racial characteristics might to some extent account for these striking differences, but it appears to me that the real reason lies in the very favorable conditions under which the northern children live. Child neglect in rural areas is exceedingly rare. There is still a rather sterner training in character given by country parents, and the families not only prove physically superior, but seem to rise to positions of responsibility and trust wherever they go. The success of country-bred persons in city life has often been remarked; they are found as financiers, as leading professional men, as the heads of businesses, and as managers and foremen in industry. The managing director of one of the largest manufacturing concerns in England recently stated that in his experience the best foremen, with respect to the command of men, resource and engineering intelligence, have been country-bred boys, and that the best and steadiest workmen also come from the country.

If, then, rural conditions produce, as they appear to do, a race physically and mentally fit, showing a superiority over those born of parents possibly financially better off, but by the accident of birth condemned to spend the whole period of growth in the more or less unhygienic environment of industrial centers, it would seem desirable from every point of view that as large a proportion as possible of the population should live in rural areas. Unfortunately, however, the present tendency is toward greater concentration in industrial localities and a declining rural population. The urban population in the United Kingdom now accounts for 80 per cent. of the total inhabitants, and the urban is always growing at the expense of the rural. With this diminution of the country population there has been concurrently a closing-down and shutting-up of many rural industries, so that the modern tendency is still toward concentration of manufactures near the centers of population. This development of industry has in the past proceeded in a haphazard way, with no central authority controlling or taking any special interest in the matter. Consequently we find extraordinary congestion in certain areas of the country, and other localities equally neglected although affording good facilities for manufacturing purposes. Industries all dealing with the same material and employing a preponderating proportion of one sex have grouped themselves in certain towns and rendered general development difficult,

inasmuch as an industrial community to be economically sound should have a proper proportion of each sex employed. At the present time there are areas in the United Kingdom where the demand for female workers cannot be satisfied and yet where no employment is offered for men, and *vice versa*.

The difficulties would be overcome were industries better distributed, and distributed in such a way that the sexes would be adequately balanced. Thus, it has been found advantageous to have spinning and weaving, and the manufacture of hosiery in mining districts so as to afford employment for the daughters of pitmen, and equally desirable to have engineering and like trades in textile districts so as to afford employment for the heads of families, without which obviously there would be no successive generation of young people to staff the textile factories.

The establishing of new industries in rural areas is always attended by the initial difficulty of lack of trained labor on the spot, but recent practice on the part of certain large firms has been to erect houses for present and future workers, and when this is done almost ideal conditions can be secured. Indeed, a judicious pushing out into rural areas of industries planted in the midst of already congested towns would tend to solve automatically many pressing problems of public health. Judging by past experience, not only would the infantile death rate be lowered, but a healthier and better-grown race of young workers would be reared. Incidentally, I may mention that there appears to be some definite association between degeneracy in physique and a high infantile death rate. In rural areas, where the infantile death rate is usually very low, there the standard of physical fitness is high; in the textile towns of Lancashire where the infantile death rate ranks high, the standard of physique, judging by the conditions revealed in the medical examinations for military purposes, was almost uniformly poor. In the densely populated area of Lancashire and Cheshire, for instance, in which the textile industry predominates, out of 1,070 recruits of 18 years of age examined, no fewer than 451 (or 42 per cent.) were less than 112 pounds in weight and 142 of them (or 13 per cent.) were less than 100 pounds in weight. The chairman of the medical board in this region, commenting on the physical standard of recruits, remarks that the average person here is for military purposes an old man before he is 40. On the other hand, the proportion of Grade I recruits in agricultural areas is almost invariably high. This was the experience of the medical boards throughout England and Scotland. Miners reached almost the same standard, especially where the pits were located in rural areas and the recruits had been brought up in virtually agricultural conditions, many of the young miners being the sons of small farmers. This was particularly exemplified in the western portion of the Welsh coalfield.

The fine physique of the territorial Highland regiments, largely drawn from agricultural and pastoral districts, was generally recognized, and among our colonial troops the Australians — again a class chiefly engaged in outdoor callings — were remarked for their tallness. Further, our police force, which demands a high standard of stature and fitness in young men joining it, draws its recruits very largely from the class which follows the plough. Further examples could be given but these will suffice to prove that where early life is spent largely out of doors, as nature intended it should be, a good standard of height and weight is usually attained, even though the diet is simple in character and without much variation.

It has been demonstrated repeatedly that the physique of the moneyed and professional community is good, the standard be-

ing the best of all classes, and the reasons are fairly obvious. The children of this class are carefully nurtured, have ample sleep, outdoor exercise, and organized games, and a special interest is taken in their development and growth. Similarly, the children of skilled artisans, especially in towns, have advantages over the offspring of the poorer paid, unskilled city laborers, inasmuch as they benefit from the parents' higher wages and enjoy such hygienic conditions as the father's purse affords. The relative position of recruits drawn from this class is clearly shown; out of 40,000 examined in the London region, 37 per cent. were of Grade I, while of those engaged in unskilled labor only 27 per cent. attained this standard, and the percentage suffering from specific disease was much higher than among those drawn from the skilled trades.

Until the last great European war there had never been any call to have an anthropometric survey of the young manhood of the nation, and the usual impression held by the public was that the physique appeared quite good and the general health equally so. Those who, like myself, came much in contact with the toiling masses of the large cities and noticed their stunted size and the extraordinary commonness of deformity, especially of the lower limbs, occasionally expressed doubt if all was well, but the community generally refused to admit any particular deterioration. The medical examination of all men drafted into the army, however, for the first time in our history, gave some definite idea as to how we stood. The conditions revealed must be considered as seriously disquieting so far as our own young manhood is concerned. As for women, there has unfortunately been no corresponding survey, but my own observations suggest — there are no figures at present available, and it is only my impression — that the conditions and environment, which adversely affect the healthy growth of men, have an equally injurious effect on women. In agricultural districts where the men are well grown, so are the women; in the densely populated manufacturing centers where the men are stunted in height and light in weight, the women correspond. This is as one would expect, as the sexes share in the home conditions, be they good or bad, and enter employment at much the same age. If anything, girls have less opportunity for open-air exercise during growth than boys, and while a small proportion of industries, open-air or partially open-air in character, are available for boys, most women's occupations are indoor, and a vast number sedentary in character.

Continental countries have for years had annual examinations of recruits drawn from all classes and have thus had an opportunity of estimating effects of town and country life and industry on the growth of the young manhood. The only figures I have seen, those relating to Germany, show very much the same results as are observed in the United Kingdom as regards the superiority of the agricultural classes over the city and industrial classes. When this was recognized in Germany efforts were made to attack the causes of deterioration and to encourage rural industries and agriculture so as to secure as large a proportion as possible of men of high military value.

It must be admitted that there has been lamentably little interest taken by the community generally in the physical fitness of the race. This seems somewhat extraordinary in a nation which has been phenomenally successful in the breeding of cattle, horses and sheep. The previous apathy must be put down largely to ignorance of the real conditions, and to the fact that prior to the late war the physical efficiency of the manhood of the country had never been severely tested. The vast majority of occupations make no searching demand on the stamina of the persons who follow them; there are usually light proc-

esses which can be carried on by weak or even slightly deformed operatives, and so long as the work is done and suitable labor is available there is no particular cause for comment. When, however, the whole future of the state depended, as it did, on the fighting efficiency of its armies, the health of each individual member assumed at once a position of the very highest importance, and now that this has been definitely realized, the physical welfare of any class, however humble, can never again be allowed to be a matter of indifference.

TABLE 1.—DIFFERENCES IN HEIGHT AND WEIGHT OF WORKMEN OF RURAL AND OF URBAN ORIGIN

Class of Men	Number Examined	Height in Feet and Inches	Weight in Stones and Pounds	Age
Country-bred men	440	5–8.8	12–4	20 to 55
Public school men, military cadets, etc.	proportion of 7,000	5–9.06	11–1.2	20 to 30
Sheffield grinders	1,080	5–4.55	9–10.13	25 to 55
Birmingham brass workers	500	5–6.6	9– 8.0	25 to 55
*Glasgow laborers	230	5–2	8–12	18 to 40
*Glasgow engineers	280	5–5	9–1	18 to 40
*Glasgow joiners	55	5–4	9–9	18 to 40
*Glasgow carters	37	5–2	9–3	18 to 40
*Manchester recruits (Grade 1)	1,000	5–5	8–8.6	Average 28
*Ashton-under-Lyne (Grade 1)		5–4	8–10.5	30
*Bolton (Grade 1)		5–4	8–13	23
*Liverpool (Grade 1)		5–5	9–0.5	23
*Preston (Grade 1)		5–5	9–0.8	28
*Bury (Grade 1)		5–5	8–13	29
*Accrington (Grade 1)		5–5	9–5.9	29
*Lancaster (Grade 1)		5–6	9–2	21
*Warrington (Grade 1)		5–5	9–2.8	23
*Chester (Grade 1)		5–6	9–3.9	25

* Army recruits, *Report upon Physical Examination of Men of Military Age* by National Service Medical Boards (Cmd. 504). Note the slight advantage the Chester and the Lancaster recruits possess in height over those from larger and more essentially manufacturing towns. The above figures relate to Grade 1 men; statistics relating to an additional 1000 Grade 2 men from the same towns show materially worse physique.

Industrialism, the source of most of our wealth and position in the world, has brought about conditions, so far as the laboring masses are concerned, very different from those which existed in our earlier history when agriculture was the chief occupation and the community was scattered in isolated farms and small villages. Indeed, our ancestors, without perhaps being aware of it, were working on almost ideal lines for securing a healthy race of men and women, the children always in clean air, fed on the simplest but most wholesome of food, and the vast majority of men occupied all their lives in outdoor work.

Disquieting as are the facts revealed by the examination of recruits in the United Kingdom, the future is not without hope. The public conscience has been awakened, the whole housing question is being attacked, the school age is being extended, and the hours of employment have already been reduced, affording more leisure, more opportunities for games and open-air exercise, and, perhaps most important of all, more sleep for the young. Undoubtedly, curtailed sleep in the past was a serious evil and was chiefly due to the unnatural hour (6 A.M.) of commencing work. Further, more holidays are being taken, wages are higher and notwithstanding increased cost of living, children are unquestionably being better clothed and better fed than they were prior to 1914.

If more industries would move out of the crowded areas and establish themselves in clean, wholesome surroundings, and take some responsibility for the comfortable housing of their employees, as certain enlightened firms have done, an improvement in physique of the next generation of young workers would certainly follow. Indeed, this improvement has already been clearly demonstrated where the garden-city idea, in association with industry, has been adopted.

Of statistics dealing with the physique of adolescents we have practically none, but as the adult represents the result of all the environmental influences, good and evil,

acting and reacting on him during his whole growing period, he may be taken as representative of his class.

In conclusion, therefore, I give a table combining statistics obtained from the medical examination of recruits, together with others collected partially by myself, which show differences in height and weight of workmen of purely agricultural origin who had spent the whole of their period of growth in rural districts, and craftsmen and laborers born and brought up in industrial towns. Special care was taken to insure that the country workers had in every case resided in rural districts until full-grown. Most of the number measured were employed as navvies, but a proportion were engaged in salmon-fishing combined with agricultural work, and a few, although brought up to farm work, were later employed as laborers in iron and steel works.

THE EFFECT OF THE INHALATION OF GASES*

G. A. WELSH, M.D.

Medical Officer to H. M. Factory, Gretna

DURING the course of employment in the manufacture of nitric acid and sulphuric acid and in the varied processes for which these acids are used in the manufacture of cordite, the operatives are exposed to the effects of inhaling gases and gaseous vapors. The gases and vapors met with in the various plants are: sulphur dioxide (SO_2), sulphur trioxide (SO_3), chlorine (Cl), nitrosyl chloride (NOCl), compounds of nitrogen and oxygen, chiefly nitrogen peroxide (NO_2), and carbon monoxide (CO) contained in producer gas. The vapors are sulphuric acid in the form of a mist and nitric acid in the form of a mist. There are also nitric acid fumes and sulphuric acid fumes from concentrated acids. Records of cases treated at H. M. Factory, Gretna, show 361 persons who suffered from gassing.

The effects of a gas or an acid mist vary according to the quantity inhaled. If a sufficient quantity is inhaled at one time the condition is properly called gassing. The signs and symptoms are acute and, except in the case of carbon monoxide, are, for the most part, due to the irritant action of the gas. There is another aspect, however, which must not be lost sight of. If the same gas or mist is inhaled in small quantities over a long period, it is capable of causing ill health. I propose to deal with these cases separately. They are cases of systemic poisoning and not gassing. I will also deal separately with carbon monoxide which is not an irritant gas like the others. There are of course differences in the effects produced in cases of gassing. Some workers stand larger quantities than others, the amount of effect varying, a high degree of resistance being reached in those who are thoroughly acclimatized to the work. A new worker is more readily affected than one who has been a year in the plant, and a foreman of long experience may be little affected by quantities which affect severely the other less acclimatized workmen. Striking examples of this are found in plants where the gases are highly irritant and where, owing to the nature of the operations, the gases are more frequently found in the atmosphere — e. g., nitric acid retorts, and the plants where concentrated acids are mixed for use in nitration. In this connection it is of great importance that every worker should be medically examined and classified for work. A man with weak eyes or who suffers from pharyngitis, laryngeal catarrh or any lung affection is not a suitable person for work in an acid plant. I have records of cases where the inhalation of a moderate amount of gas caused a severe attack of bronchitis in a person predisposed to it, and others where it directly caused a quiescent lung tuberculosis to become active.

Effects of Various Gases

Volume for volume the compounds of sulphur and oxygen are not so dangerous as the compounds of nitrogen and oxygen or the compound, nitrosyl chloride. Similarly, the vapors of sulphuric acid are not so harmful as those of nitric acid. A gas in an anhydride state does not affect the skin — e. g., sulphuric anhydride and nitrogen peroxide; it causes smarting of the eyes and lachrymation and acts on the mucous membranes of the mouth, naso-pharynx, larynx and bronchi. A gaseous vapor — e. g., sulphuric acid mist or nitric acid mist

* Received for publication June 21, 1920.

— in addition to affecting mucous membranes, informs you of its presence by irritating the thin epidermis on the face and back of the hands.

A person who is gassed by an irritant gas complains first that he has difficulty in inspiration. His inspiration is shallow and frequent and he coughs at once if he attempts to breathe deeply. With this there is breathlessness on any exertion and thumping of the heart on the chest wall. The patient says that his chest feels tight and there is also a feeling of constriction in the larynx. Soon he complains of dryness and burning in the pharynx and there is evidence of laryngeal irritation in the form of a short persistent cough. He develops a headache with throbbing over the temples, feels sick and in some cases actually vomits. He has an anxious expression, feels ill and has a full bounding pulse; cyanosis may show in the face and thumb nails. In the course of an hour or two there is a slight rise of temperature. Physical examination of the chest shows harsh vesicular breathing and occasionally there are some low pitched rhonchi; the heart rate is frequent and the sounds are accentuated. If it is a severe case, the extraordinary muscles of respiration are called into play. The severity of these symptoms varies with the amount inhaled.

In order to estimate the gravity of a case it is essential to know what is the substance causing gassing. With this knowledge and judging from the severity of the signs and symptoms, it is possible to give a fairly accurate prognosis in all cases except those of gassing by nitrogen peroxide and nitric acid mist. In the case of nitrogen peroxide and nitric acid vapors, one must be very guarded because the effects may be slight at the time and give no indication of the amount of damage done to the lung. A man gassed by these compounds may become suddenly ill some hours afterwards and develop acute capillary bronchitis of a suffocative variety with edema of the lung. Cases in which chlorine or nitrosyl chloride is the cause of trouble may appear very alarming at the time but one knows from experience that the chances are in favor of the signs and symptoms settling down, and recovery taking place. The urgency of the symptoms in these cases is due more to spasm than to tissue change. Expectoration of blood is a common occurrence in gassing. If the blood is small in amount and mixed with mucus it is not of serious import; it may persist for two or three days. A large hemoptysis is evidence of pre-existing lung mischief. In nitrogen peroxide cases, expectoration of a blood-tinged serous fluid is a grave sign, indicating capillary bronchitis with edema of the lung.

Severe cases of gassing are kept under observation in the rest room until all dangerous symptoms subside. In the majority of the cases the urgent symptoms subside in twenty-four hours; a few last for forty-eight hours. It is then a question of dealing with what is left, pharyngitis, laryngitis, bronchial irritation or bronchitis. For a few days the patient complains of being out of sorts, is restless, without appetite, constipated and sleepless. A patient with a moderately severe case of gassing which resolves without complications is able to return to work in from seven to ten days. Any complications — e. g., laryngitis or bronchitis — of necessity prolong the incapacity and render it unwise to return the operative to work until the condition has fully cleared up. I always give these patients a change of air and surroundings for a week before certifying them as fit to return to work.

Gassing with carbon monoxide presents a different picture, as carbon monoxide is not an irritant gas. It acts, as is well known, by combining with hemoglobin to form CO-hemoglobin, causing a deficient supply of oxygen to the tissues. Its affinity for hemoglobin is greater than that of

oxygen and, if present in the air breathed, its gradual absorption destroys oxyhemoglobin. All my cases, with the exception of two, inhaled the gas in small quantity and were not serious. The patients were working alongside of other workmen and their condition was recognized in the early stages. The patients in two serious cases inhaled the gas in a close space. They were working alone, and were found unconscious, one suffering from epileptic convulsions and the other from heart failure. The patient with heart failure was a chemist who walked out of his office which contained carbon monoxide into the cold air. Both men recovered.

Treatment of Gassing

Preventive

It is very important to acquaint the operatives thoroughly of the dangers they run by inhaling these gases. This is systematically done, and warning notices, especially in connection with nitrogen peroxide, are posted in the plant and incorporated in the workmen's book of factory rules.

The wearing of respirators by operatives was carefully considered, but after many trials it was discontinued. The operatives themselves do not like wearing respirators and as the cases of gassing are generally the outcome of some accident it is impossible to be sure that the operative will be wearing a respirator at the time of the accident. As an exception, there is one case I would like to mention — that of the nitrocotton dippers. They wear a simple respirator of moist cotton wool well over the mouth and nose. This traps the vapors from the mixed acid up to a certain point and the men feel the benefit of it, but it cannot be called an efficient respirator. Short of a self-contained apparatus, nothing has been found to trap nitrogen peroxide fumes efficiently. It sometimes happens that a building may rapidly fill with fumes as the result of an accident and for this emergency we use a self-contained apparatus, the Mecco. The principle of this apparatus is that for a known period the wearer is independent of the atmosphere round about him, oxygen is supplied from a cylinder and the carbonic acid in the expired air is removed by absorption with caustic soda. A number of operatives have been trained in the use of this apparatus and form what we call a rescue brigade. This brigade is used in any case where it is necessary for the workmen to be in the plant in the presence of dense fumes. It is also ready for an accident where workmen might be trapped by dense fumes and not be able to get out of the building. Fortunately, on only one occasion has its use been necessary.

First-Aid Treatment

The following instructions are printed in the factory rule book:

Nitrogen Peroxide Fumes. — To treat a person gassed with nitrogen peroxide fumes — remove at once to the fresh air and lay out flat. If a severe case the patient should be carried out and not allowed to walk.

Take care that the heat of the body is kept up by covering with blankets and, if need be, use hot water bottles.

One dose of chloroform solution should be given at once and the patient seen by a doctor as soon as possible.

N. B. — If there is a marked difficulty in breathing or if the face is dusky blue in color, oxygen should be administered at once.

Producer Plant Gas. — All workers are warned that carbon monoxide is one of the constituents of producer gas. When this gas is inhaled in a closed space it may cause serious illness in the worker.

A considerable quantity may be inhaled before its effects are produced and the worker may become unconscious without feeling much the matter beforehand.

Giddiness, shortness of breath on slight exertion, thumping of the heart and an unsteadiness in the legs are the symptoms which may first show themselves.

To treat a person gassed with carbon monoxide gas, he should be at once removed from the poisonous atmosphere but not brought suddenly in contact

with cold air, as this may produce a serious condition from heart failure. The person should not be allowed to walk but should be carried out into a pure atmosphere and kept warm with blankets and hot bottles. If the breathing is shallow or has stopped, artificial respiration should be at once begun and oxygen administered from a cylinder. The doctor should be informed at once of such an occurrence and unless the person is too seriously ill to be removed he should be taken to the first-aid station without delay.

In the first-aid boxes there are unit doses containing 20 drops of spirits of chloroform, 3 drops of liquor strychninae hydrochloridi and water to one tablespoonful, and Seidlitz powders. There is also placed in each plant an oxygen cylinder containing 20 feet of oxygen. These cylinders are easily manipulated, the reducing valve being opened by means of a wheel and the oxygen conveyed to the person by a rubber tube with a vulcanite mouthpiece. As a means of administering oxygen they are most efficient. In slight cases, a dose of chloroform mixture, followed by a Seidlitz powder and a few hours' rest is quite sufficient. If the case is more severe, the patient is taken up to the rest room and is put to bed and plenty of fresh air allowed to play round about him. His bodily heat is maintained by means of blankets and hot bottles until a state of mild perspiration is reached. Marked difficulty in breathing and cyanosis is treated by administering oxygen, a dose of chloroform mixture every four hours, and in the way of food nothing but hot milk is given. In the nitrogen peroxide cases, the administration of oxygen is continued until all signs of danger are passed.

Only one case of gassing has had a fatal termination. This was a man who was working in a closed space and inhaled the vapors of fuming nitric acid. He died from the effects of nitrogen peroxide. The report on the post-mortem examination follows:

External Appearances. — The body was that of a man about 5 ft. 9 in. in height, and was fairly well nourished. Post-mortem rigidity was present in a slight degree; post-mortem lividity was well marked over the dependent parts of the body. There were no marks or bruises.

Examination of the Respiratory Passages. — The larynx and trachea showed no abnormal change. The extra-pulmonary bronchi with the large and small bronchi in the lungs were the seat of congestion with patches of ecchymosis. There were numerous tough fibrous adhesions between the lungs and chest wall especially marked and widespread over the lower lobe of the right lung posteriorly. These adhesions were not of recent origin but were evidences of old inflammatory lesions. There was slight emphysema of the anterior margins of the upper lobes of both lungs. Both lungs were the seat of a severe acute bronchitis with edema and patches of hemorrhage into the lung substance. There was no sign of pneumonic consolidation but the lung substance was friable and had to a great extent lost its elasticity. A small quantity of serous fluid was present in both pleural sacs.

Examination of the Heart and Large Blood Vessels. — The pericardium showed no abnormal change. The right ventricle and auricle were dilated and filled with soft blood clot. The left ventricle and left auricle were contracted and empty. The superior vena cava, the inferior vena cava and the pulmonary artery were distended with soft clot and fluid blood. In short, the right side of the heart was dilated and the circulation in connection with it engorged. The valves of the heart showed congestion but there were no adhesions and the valves were competent. The heart muscle was very dark in color. The blood was dark purple in color showing marked evidence of deoxygenation.

Systemic Poisoning from Inhalation of Gases and Gaseous Vapors

From time to time examples of what are called systemic poisoning have come before my notice. This condition occurs in operatives who have never suffered from gassing but who from time to time have inhaled small quantities of fumes. I have no doubt, after careful inquiry, that it is the inhalation which causes the condition. A common history is that the onset was gradual, that the condition became worse after each successive inhalation and that eventually the patient became unfit for work. Such a patient is anemic, complains of headache, sleeplessness, loss of appetite, loss of energy and capacity to do work, and suffers from a torpid dyspepsia with marked flatulence and constipation. In treating these patients I have found that as long as they are kept at work no system of treatment benefits their condition. As soon as they are removed from work and sent for a change of air, very simple treatment puts them right. The most successful method of treatment for these patients is to put them on a light fluid diet and treat them with an alkaline saline mixture.

A number of patients suffer from acute gastro-enteritis due to inhalation of small quantities of gas. I have also seen operatives with numerous ulcers affecting the lips, buccal mucous membrane and pharynx. These ulcers are intractable and resist all forms of treatment as long as the patient remains at work; when he is removed from work a simple mouth wash suffices for their healing. A number of cases complain of naso-pharyngeal catarrh; this also resists treatment till the patient is removed from work, when simple methods clear up the condition. I have seen no cases which would lead me to say that this systemic poisoning results in any permanent form of incapacity. At no time have I seen cases in which jaundice was a complication nor have I seen any cases where the anemia was intractable.

The question of the effect on the teeth has come up from time to time and, after sifting every case, I have found no instance where the fact that men were working in an atmosphere of gases and vapors caused decay of sound teeth. On the other hand, evidence seems to show that in a tooth which is already diseased, the process of decay is more rapid. Operatives are warned in every case to pay especial attention to the cleansing of their teeth.

INDUSTRIAL TUBERCULOSIS AND THE CONTROL OF THE FACTORY DUST PROBLEM *

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PART I

PRESENT DAY PROBLEMS OF TUBERCULOSIS

IN the development of any science there are alternating periods of positive theoretical advance and negative critical reaction. Both are essential to sound progress; yet the critical phase is of necessity somewhat trying to the souls of those whose interest lies in the immediate practical application of scientific principles for the furtherance of the well-being of mankind.

Our knowledge of the etiology of tuberculosis is at the present time passing through such a period of sceptical criticism. We know that there are two distinct factors involved in the production of an active case of tuberculosis — the number and virulence of the army of invading germs, on the one hand, and the mysterious complex of physiological factors called vital resistance, on the other; but as to the relative significance of these two factors we find no general consensus of agreement. There are those who maintain that lowered vital resistance is the one supreme determining condition and that tuberculosis, among adults at least, is not, for practical purposes, to be considered as a communicable disease. There are other authorities who, with somewhat less valid reasons, exalt the part played by the invading organisms and would treat tuberculosis from an administrative standpoint, as nearly as public opinion will permit, as we treat smallpox or scarlet fever.

Even the remarkable decrease in the death rate from tuberculosis during the past half century is interpreted in the most diverse ways. We are told by some of those who hold the reaction of the human body to be the chief controlling factor that vital resistance has been increased with the general improvement in the social and economic conditions of civilized life, or that it has been intensified by a process of hereditary selection. The believers in the dominant importance of the invading microbe in the etiology of this disease suggest that it is the tubercle bacillus which has been modified to a lower degree of virulence by hereditary forces operating upon its germ-plasm.

These current theories are alike in only one respect. They all attribute the decrease in tuberculosis to more or less vague and mysterious forces, which are at present beyond the region of deliberate human control. Some of them will, no doubt, prove definitely constructive in the future; but at present they tend to a general scepticism in regard to our anti-tuberculosis program, without the concrete suggestion of any alternative methods of dealing with this vital problem.

To the sanitarian who is actively engaged in the daily struggle against preventable disease, it is a relief to turn to one phase of the tuberculosis problem where his feet rest on firm ground. In certain trades and occu-

* Received for publication Aug. 30, 1920.

pations we find a definite condition — the presence in the atmosphere of fine particles of mineral and metallic dust — so clearly associated with an enormous excess of respiratory mortality as to leave no reasonable doubt that the dust is the effective factor in causing the disease. The occupations so affected are, it is true, insignificant in the number of men employed as compared with the industrial life of the nation as a whole, yet it is encouraging to remember that there is at least one small field of the broad tuberculosis problem in which definite and practical measures of control can be made effective wherever it is determined to put them into force. The object of the present paper is to review the evidence which indicates a direct causal connection between atmospheric dust and industrial tuberculosis, and to point out the practical methods by which the hazards of the dusty trades may be practically controlled.

The Relation between Dust and Respiratory Disease in Certain Occupations

The excessive incidence of tuberculosis among workers exposed to the pernicious influence of certain types of atmospheric dust has been noted for centuries by students of industrial hygiene.

Georges Agricola in *De Re Metallica* (translated from the first Latin edition of 1556 by one of the greatest of present day Americans, Herbert C. Hoover, and L. H. Hoover) discusses the hazards of mining as follows:

> Where water in shafts is abundant and very cold, it frequently injures the limbs, for cold is harmful to the sinews. To meet this, miners should make themselves sufficiently high boots of rawhide, which protect their legs from cold water; the man who does not follow this advice suffers much ill-health, especially when he reaches old age. On the other hand, some mines are so dry that they are entirely devoid of water, and this dryness causes the workman even greater harm, for the dust which is stirred and beaten up by digging penetrates into the windpipe and lungs, and produces difficulty in breathing, and the disease which the Greeks call $\alpha\sigma\theta\mu\alpha$ (asthma). If the dust has corrosive qualities, it eats away the lungs, and implants consumption in the body; hence in the mines of the Carpathian Mountains women are found who have married seven husbands, all of whom this terrible consumption has carried off to a premature death. At Altenberg in Meissen there is found in the mines black pompholyx, which eats wounds and ulcers to the bone; this also corrodes iron, for which reason the keys of their sheds are made of wood. Further, there is a certain kind of cadmia [probably cobalt] which eats away the feet of the workmen when they have become wet, and similarly their hands, and injures their lungs and eyes. Therefore, for their digging they should make for themselves not only boots of rawhide, but gloves long enough to reach to the elbow, and they should fasten loose veils over their faces; the dust will then neither be drawn through these into their windpipes and lungs, nor will it fly into their eyes. Not dissimilarly, among the Romans* the makers of vermillion took precautions against breathing its fatal dust.

Ramazzini in his famous work on the *Diseases of Artificers and Tradesmen* (1700) states that stone cutters "oftentimes suck in, by inspiration, the sharp, rough and corner'd small Splinters or Particles that fly off; so that they are usually troubled with a cough, and some of 'em turn Asthmatick and Consumptive." He adds: "And in dissecting the corps of such Artificers, the lungs have been found stuffed with little Stones. Diemerbroek gives a curious Relation of several Stone-cutters that dy'd Asthmatick, and were open'd by him; in whose Lungs he found such heaps of Sand, that in running the knife through the Pulmonary Vesicles, he thought he was cutting some Sandy Body."

Thackrah in his treatise on *The Effects of the Principal Arts, Trades, and Professions on Health and Longevity* (Phil. Ed., 1831) emphasizes the seriousness of respiratory disease in various dusty occupations. He

* (Pliny, XXXIII, 40.) "Those employed in the works preparing vermillion cover their faces with a bladder-skin, that they may not inhale the pernicious powder, yet they can see through the skin."

states that miners in the north of England "suffer considerably when employed in ore in the sandstones, but are sensible of no inconvenience where the ore is in limestone." He cites a parallel condition among the grinders of Sheffield: "The fork-grinders, who use a *dry* grindstone, die at the age of 28 or 32, while the table-knife grinders, who work on *wet* stones, survive to between 40 and 50." Draw-filing of cast iron was at this time an exceedingly hazardous operation.

> The particles rise so copiously as to blacken the mouth and nose. The men first feel the annoyance in the nostrils. The lining membrane discharges copiously for some time, and then becomes preternaturally dry. The air-tube is next affected. Respiration is difficult on any increase of exertion, and an habitual cough is at length produced. At the same time, the digestive organs become impaired; and morning vomiting, or an ejection of mucus on first rising, is not infrequent. The disorder varies of course with the constitution of the individual; but the common termination, when men pursue the employment for years, is bronchial or tubercular consumption.

In more recent times, the statistics of industrial tuberculosis among steel grinders at Sheffield, England, and at Solingen, Germany, have been widely quoted in many of the textbooks and monographs upon this subject.

American Studies of the Ratio of Tuberculosis Deaths to Total Deaths in Various Industries

Data obtained in regard to the prevalence of occupational disease in different countries and at different periods of time must be interpreted with the greatest caution on account of the fact that industrial processes differ so widely and change so frequently. Recent statistics for the United States are necessary to throw a clear light on this problem, and such data, in order to be of conclusive value, should be available in the form of actual death rates, based on knowledge of the population exposed as well as on the number of deaths occurring, and properly corrected for the age distribution of the group involved.

Unfortunately, such complete statistical data as we desire are difficult to obtain in the existing state of American vital statistics, exact knowledge of the population at risk in a given occupation, classified by age, being obtainable only with great difficulty and by special and intensive research. For the most part, therefore, students of this subject have fallen back on an indirect index of the tuberculosis death rate, in the form of a ratio between deaths due to tuberculosis and those due to all causes. Data of this sort may, of course, be obtained with ease from the mortality records in any registration office or actuarial department. The hypothetical conclusion to which they lead may be illustrated as follows.

If the normal death rate from all causes at a given age period be 10 per thousand and 25 per cent. of the deaths are due to tuberculosis, the actual death rate will obviously be 2.5 per thousand for tuberculosis and 7.5 for all other causes. We find in certain specific occupations that the ratio of tuberculosis deaths to total deaths is respectively, let us say, 40 per cent., 50 per cent., and 60 per cent. of the deaths from all causes. We then assume — and here is the dangerous part of the argument — that the death rate from causes other than tuberculosis remains the same in all the groups under observation. If this be the case, the tuberculosis death rate in the three occupational groups will be $40 \times 7.5 \div 60$, $50 \times 7.5 \div 50$, and $60 \times 7.5 \div 40$, or 5.0, 7.5 and 11.2 per thousand respectively. The problem has nowhere been stated in quite this baldly quantitative form, but some such assumption must tacitly underlie the use of all such ratio statistics.

Three important studies of this kind have been made in the United States during the past decade. The first of these is con-

tained in bulletins of the U. S. Bureau of the Census giving the proportionate mortality by occupations of the population of the registration area for 1908 and 1909. The second is a bulletin on the industrial experience of the Metropolitan Life Insurance Company by L. I. Dublin, published as Bulletin 207 of the U. S. Bureau of Labor Statistics (1). The third, and most extensive collection of statistics of this type, is contained in a series of exhaustive monographs by F. L. Hoffman of the Prudential Insurance Company of America, the last and most important of which was published in 1918 as Bulletin 231 of the U. S. Bureau of Labor Statistics (2).

In the analysis of statistical data of this sort, it is clearly most important that the groups under consideration should be fairly comparable, so that the effect of industrial hazards will not be complicated by the influence of social and economic factors of a more general nature. In Mr. Hoffman's studies, for example, ratios presented for the various dusty trades are based on the industrial experience of the Prudential Insurance Company, but Mr. Hoffman uses as a norm for comparison the ratio for males in the registration area obtained from the data of the U. S. Census Bureau. On this basis almost all of the industries which he tabulates show a surprisingly high tuberculosis ratio, including many trade designations of workers, like "iron and steel workers," who can hardly be considered as generally exposed to a serious dust hazard. These results, as presented in the earlier publications of the Prudential Insurance Company, aroused the suspicion that the whole group covered by industrial policies might be a selected one, and in the most recent of Mr. Hoffman's reports (2) the solution to the problem is at last presented. In this report as a whole the old comparison is presented of tuberculosis ratios in each "dusty" trade among industrial policy-holders, with the ratio for all males in the registration area, but in one place (Table 11, p. 56) Mr. Hoffman gives the ratios for all occupied males in the Prudential experience. From this table it appears that the industrial policy-holder group does, as a matter of fact, exhibit a consistently higher ratio for all occupied males, irrespective of exposure to dust. Mr. Hoffman's abnormally high ratios are, therefore, due in large part to the general social and economic conditions of the wage earner's life.

This constant difference between the Prudential figures and the census data is clearly brought out in Table 1, which we have compiled from the tables in Mr. Hoffman's bulletin so as to include all the industries exposed to metallic or mineral dusts for which 500 or more deaths from all causes at all ages were available. It is evident that in almost every instance where the two series can be compared the Prudential ratios are from 25 to 50 per cent. higher than those for the registration area.

It seems evident that a comparison between the Prudential figures for a given dusty trade and the census figures for all occupied males is not a fair one, and that the conclusion indicated by such a comparison — namely, that such groups as the iron and steel workers experience an excessively high death rate from tuberculosis as a result of the dust hazard — is unwarranted. As a matter of fact, comparisons made in each case with the corresponding groups — census figures for a dusty trade with census figures for all occupied males, or Prudential figures for a dusty trade with Prudential figures for all occupied males — show that the tuberculosis ratio for the iron and steel workers is about normal, as might be expected for so diversified an occupational group.

Comparing specific trades in the Prudential experience with the Prudential group as a whole, and comparing specific trades in the registration area with the registration

group as a whole, both sets of data are highly illuminating and bring out very clearly the excessive tuberculosis ratios characteristic of certain occupations. The two sets of figures, allowing for the constantly higher ratios throughout the Prudential experience, check each other very closely, even in such details as the concentration of the highest ratios at ages under 35 among jewelers, and at ages over 35 among marble and stone cutters.

It is interesting to notice that Dr. Dublin's statistics for the industrial experience of the Metropolitan Life Insurance Company (1) correspond almost exactly with the Prudential figures. For all males in the Metropolitan experience, the ratio of tuberculosis deaths to total deaths was 33.8 per cent. at ages 15–24; 40.9 per cent. at ages 25–34; 32.9 per cent. at ages 35–44; 18.5 per cent. at ages 45–54; 8.6 per cent. at ages 55–64; 2.9 per cent. at ages 65 and over; and 20.5 per cent. for all ages over 15. These figures are almost identical with those presented in the upper line of the right hand half of Table 1, and it is evident that the ratios shown are characteristic of the industrial group as a whole.

TABLE 1.—RATIOS IN PER CENT. OF TUBERCULOSIS DEATHS TO TOTAL DEATHS IN OCCUPATIONS EXPOSED TO MINERAL AND METALLIC DUSTS *

Occupation	U. S. Registration Area Age Groups						Prudential Experience Age Groups					
	15–24	25–34	35–44	45–54	55–64	15 and over	15–24	25–34	35–44	45–54	55–64	15 and over
All occupied males	28.1	30.9	24.0	14.4	7.6	14.9	33.2	40.9	32.9	19.0	8.8	20.5
Brick, tile and terra cotta workers	..	..	..	..	..	..	22.9	35.3	19.8	18.6	10.7	15.6
Iron and steel workers	19.8	26.1	23.3	16.7	8.5	16.9	30.0	34.1	31.3	14.7	8.7	21.0
Plasterers	25.0	31.5	34.5	16.4	7.8	16.7	34.5	43.6	40.4	23.5	11.8	21.9
Molders	..	..	..	..	..	..	23.7	40.4	30.7	21.6	13.9	23.0
Paper hangers	..	..	..	..	..	..	35.1	44.0	42.5	15.7	11.5	29.1
Painters, glaziers and varnishers	30.8	36.9	29.2	17.4	9.0	18.7	..	..	..	..	..	..
Tinplate and tinware workers	39.4	36.7	34.8	13.7	6.6	18.7	..	..	..	..	..	..
Jewelers	50.0	39.7	23.4	14.1	8.5	17.8	50.9	58.3	45.3	21.2	11.1	29.3
Glassblowers	..	..	..	..	..	..	45.1	53.3	31.3	28.3	15.4	32.1
Other glassworkers	..	..	..	..	..	..	31.5	51.1	34.4	23.1	15.5	30.5
Glassworkers	47.2	42.6	33.1	19.7	7.9	30.0	..	..	..	..	..	..
Tool and instrument makers	..	..	..	..	..	..	37.5	52.7	36.9	33.7	10.4	31.9
Potters	..	..	..	..	..	..	31.2	49.6	39.8	30.2	21.1	32.2
Marble and stone cutters	26.2	43.5	44.1	41.6	23.3	30.7	38.3	51.1	44.4	39.0	26.7	33.6
Brassworkers	..	..	..	..	..	..	58.2	51.0	43.8	24.2	16.1	36.7
Compositors and type-setters	..	..	..	..	..	..	46.3	55.9	41.1	24.9	9.8	36.8
Pressmen	..	..	..	..	..	..	42.9	47.7	44.0	20.0	11.1	39.6
Printers, lithographers and pressmen	43.6	50.0	36.3	21.5	7.7	29.5	..	..	..	..	..	..
Polishers	..	..	..	..	..	..	43.4	56.1	44.0	24.9	14.3	36.8

* The figures given are taken from Bulletin No. 231, Bureau of Labor Statistics, U. S. Department of Labor.

Even when comparisons are made in the correct manner between a dusty trade and an average group of as nearly as possible the same general social and economic status, there must always be a large measure of doubt in regard to the significance of high tuberculosis ratios. Ratios, as distinct from rates, depend on two independent variables, and a high ratio of tuberculosis deaths to total deaths may be produced by a low mortality from other causes, as well as by a high mortality from tuber-

culosis. Thus, the tuberculosis ratio among female college professors and teachers, according to Dr. G. M. Kober (3), is high — a ratio which Dr. Kober attributes to the alleged fact that the teaching profession is "usually recruited from weak stock." L. M. Terman, in his book on *The Teacher's Health* (4), has also given currency to the view that teachers suffer to an exceptional degree from tuberculosis. The only careful statistical study of this subject with which we are familiar, Dr. L. I. Dublin's paper on *Physical Disability of New York City School Teachers* (5), shows that this conception is erroneous. The high ratio of tuberculosis deaths to total deaths among teachers is shown in this investigation to be due to the fact that the death rate from causes other than tuberculosis in this group is exceedingly small, the tuberculosis rate itself being less than two-thirds of the rate prevailing among females in the community at large, at the age of 15 and over.

Studies of the Actual Death Rates from Tuberculosis in Various Dusty Trades

It is by no means intended to discredit all use of mortality ratios, still less to throw doubt upon the real importance of the problem of industrial tuberculosis. We desire only to emphasize the possible fallacies in the use of ratios and the necessity for controlling deductions by the determination of actual death rates wherever possible.

In England numerous statistics are available which indicate that in many industrial employments, such as metal mining, marble and stone cutting, and grinding and polishing, high tuberculosis ratios are associated with high tuberculosis rates, exactly as might be expected from the theoretical considerations advanced above on page 335. In Table 2, for example, are presented the data for occupations exposed to metallic dusts, from the Sixty-Fifth Annual Report of the Registrar-General, rearranged and supplemented by ratio computations. They show that the excessive ratios of tuberculosis deaths to total deaths indicate an actual excess death rate from tuberculosis of one to two persons per thousand population; while at the later age periods, the death rate from causes other than tuberculosis among the workers exposed to the influence of metallic dusts is also well above the normal rate.

TABLE 2. — MORTALITY FROM PULMONARY TUBERCULOSIS AND OTHER CAUSES IN OCCUPATIONS EXPOSED TO METALLIC DUST, COMPARED WITH THAT OF ALL OCCUPIED MALES, ENGLAND AND WALES, 1900–1902

Age Period	All Occupied Males				Occupations Exposed to Metallic Dusts			
	Deaths per 1000			Per Cent. Due to Tuberculosis	Deaths per 1000			Per Cent. Due to Tuberculosis
	Total	Tuberculosis	Other Causes		Total	Tuberculosis	Other Causes	
15–19	2.4	0.5	1.9	22	2.7	0.7	2.0	27
20–24	4.4	1.5	2.9	35	5.3	2.7	2.6	52
25–34	6.0	2.0	4.0	34	6.3	3.3	3.0	53
35–44	10.2	2.7	7.5	27	11.7	5.0	6.7	43
45–54	17.7	3.0	14.7	17	21.0	5.2	15.8	25
55–64	31.0	2.2	28.8	7	36.0	3.9	32.1	11
65 and over	88.4	1.1	87.3	1	95.5	1.5	94.0	2

The earlier reports of the medical officer of health of the city of Sheffield contain particularly significant data in regard to the mortality in the intensively hazardous

processes of the cutlery industry. The report for 1910, for example, shows a mortality from pulmonary tuberculosis among grinders of 14.8 per thousand for the age of 18 and over, as compared with a rate of 2.7 for all occupied males of the age of 20 and over. The corresponding mortality from all other causes was 15.1 per thousand for grinders, and 13.7 for all occupied males; the ratio of tuberculosis deaths to total deaths was 49 per cent. for grinders and 16 per cent. for all occupied males.

Finally, we may cite one more example from the field of British industry, presented in the *Report of the Departmental Committee on the Dangers Attendant on the Use of Lead and the Danger or Injury to Health Arising from Dust and Other Causes in the Manufacture of Earthenware and China* (6). Dr. G. Reid of Stafford presents the following

TABLE 3.—MORTALITY FROM PLUMBISM AND RESPIRATORY DISEASES AMONG STAFFORDSHIRE POTTERS

Nature of Industrial Illness	Number of Workers Exposed to Risk	Average Annual Deaths Attributable to Employment	Annual Death Rate per 1000
Lead poisoning.....	5,299	4	0.8
Pulmonary tuberculosis and other respiratory diseases	21,000	148	7.0

computation (Table 3), which indicates that even in a trade like pottery making, which is generally considered as one of the industries most affected with plumbism, lead poisoning is far less important as a factor in the death rate than is industrial tuberculosis.

In the United States we have a few — but only a very few — data of this kind which show the actual death rates from tuberculosis in employments exposed to the hazards of industrial dusts. The only general collection of statistics of this sort with which we are familiar was presented in a special bulletin on *Tuberculosis in the United States*, prepared by the Bureau of the Census for the meeting of the International Congress of Tuberculosis, held in Washington in 1908. The highest and the lowest rates included in this tabulation are presented in Table 4, and they are suggestive and interesting, although the absence of an analysis by age periods detracts seriously from the value of the results, as does the fact that the occupational groups are large and often loosely defined. The high rates among cigarmakers and tobacco workers, compositors, printers and pressmen, servants, bookkeepers, clerks and copyists, and the low rates among bankers, brokers, and officials of companies are no doubt in large measure due to the age composition of the respective groups. In the high rate among servants the racial factor must certainly play an important part.

Important data in regard to the effect of mineral dusts upon the tuberculosis rate have recently been presented in the *Second Preliminary Report of the Committee on Mortality from Tuberculosis in Dusty Trades* (7), which deals primarily with conditions in the quarrying districts of Vermont. We have presented in Table 5 certain selected data from this report which indicate that in towns, and even in entire districts, where a considerable proportion of the population is exposed to mineral dust, the tuberculosis death rate for the entire administrative unit may be increased far above the normal value.

The most comprehensive study of this kind which has yet been completed was conducted by Dr. Herbert Drury in the Department of Public Health of the Yale School of Medicine, and dealt with the incidence of tuberculosis among the employees of an axe factory in the state of Connecticut. The factory in question employs about 800 men and is situated in a rural community where other industrial activities are largely agricultural. The vital statistics for the four adjacent towns

TABLE 4. — MORTALITY FROM TUBERCULOSIS IN CERTAIN OCCUPATIONS IN THE REGISTRATION STATES FOR THE AGE OF TEN YEARS AND OVER, 1900

Occupation	Deaths per 100,000	Occupation	Deaths per 100,000
Marble and stone cutters	540.5	*All occupied males*	*236.7*
Cigarmakers and tobacco workers	476.9	Steam railroad employees	129.8
Compositors, printers and pressmen	435.9	Clergymen	123.5
Servants	430.3	Miners and quarrymen	120.9
Bookkeepers, clerks and copyists	398.0	Farmers, planters and farm laborers	111.7
Laborers (not agricultural)	370.0	Lumbermen and raftsmen	107.1
All occupied males	*236.7*	Bankers, brokers and officials of companies	92.1

in which the operatives might reside have been analyzed in detail for a period of twenty years, and each death certificate for tuberculosis or other respiratory disease transcribed and investigated. The fact that the medical consultant of the axe factory and the superintendent had both been in the employ of the company during the two decades covered by the investigation made it possible to trace out practically every death certificate, and to determine the actual occupation of the deceased. The final analysis of the results yielded the astonishing figures presented in Table 6.

TABLE 5. — MORTALITY FROM TUBERCULOSIS OF THE LUNGS IN QUARRYING DISTRICTS OF VERMONT, 1906–1915

District	Tuberculosis Death Rate per 100,000 Population
State of Vermont	90.6
Granite cutting districts	143.0
Barre City (granite center)	233.2
Marble districts	97.1
Town of Dorset (marble center)	149.4
Slate districts	111.3
Town of Castleton (slate center)	176.0

Thus, we find the entire population of the mill district showing a tuberculosis rate of 200 as compared with 150 for the state as a whole. The mill population itself has a rate rising to 650, and the group of polishers and grinders the astounding rate of 1900. The other employees of the mill are not entirely comparable in age, race, and general social and economic status with the polishers and grinders, but it is evident that the high death rate among the polishers and grinders, who suffer from a tuberculosis death rate over ten times the normal rate, is primaraly due to the hazards of their occupation. Nor is tuberculosis the only form in which they pay a penalty for their hazardous employment. Dr. Drury reports that the mortality from pulmonary infections other than tuberculosis for the period 1900 to 1919 was 430 per 100,000 for the polishers and grinders, as compared with 170 for the other employees of the axe factory.

TABLE 6. — MORTALITY FROM TUBERCULOSIS OF THE LUNGS IN A CONNECTICUT AXE FACTORY, 1900–1919

	Death Rate per 100,000
State of Connecticut	150
State of Connecticut (male population)	170
Axe factory district (3 towns, entire population)	200
Employees of axe factory (all)	650
Employees of axe factory, polishers and grinders	1900
Employees of axe factory, others	160

Pathology of Industrial Tuberculosis

The effect of exposure to an intensive industrial dust hazard is well described in the following letter, written to the senior author several years ago by a physician in a small Massachusetts town where the principal industry was an axe factory much like the Connecticut factory where the statistical data cited above were obtained:

> I have seen quite a number of cases of so-called grinder's consumption. The symptoms are excessive shortness of breath on slight exertion, dry cough and great prostration. The grinders are from the Po-

landers and Finns for the past dozen years. The disease takes hold of them more frequently, and is more rapidly fatal than among the grinders of former years and of other nationalities. When I came here forty years ago I found the victims among the Yankees who had ground some 20 years before. Those would grind 18 to 20 years before having to give it up. The French-Canadians were then grinding. They could work 12 to 16 years. They became frightened off and the Swedes took up the work. They would get the disease in 8 or 10 years. Now the Finns and Polanders are at it, and they last only 3 to 5 years, and the disease is more common among them.

The most exhaustive studies of industrial tuberculosis which have so far been conducted have dealt with the mining industry, particularly the studies presented in the report on *Siliceous Dust in Relation to Pulmonary Disease among Miners in the Joplin District, Missouri* (8), and in the invaluable reports of the South African Commission (9) (10) (11).* The South African reports have made it clear that the effect of fine rock dust is to produce "a chronic disease of the lungs, characterized by progressive fibroid changes in the lung tissue and pleura, and accompanied by chronic catarrhal processes in the air cells and respiratory passages. The disease is thus primarily a fibrosis of the lung." "In the later stages tuberculosis becomes commonly or invariably superimposed upon this condition and the type of the disease becomes that of a tuberculous infection in a fibroid lung."

It is, of course, possible to find the condition of pneumoconiosis without tuberculous infection. In the examination of 720 miners of Joplin (8), Dr. Lanza reports 5 per cent. as suffering from tuberculosis without evidence of injury from dust, 46 per cent. as suffering from pneumoconiosis without evidence of tuberculous invasion, and 15 per cent. as suffering from miners' phthisis, with pneumoconiosis on which the specific infection of tuberculosis had been superimposed. According to most authorities, pneumoconiosis by itself is rarely a fatal disease, and Dr. Lanza has described old miners at Joplin with lungs so damaged by fibrosis as to be unable to work, or to ascend a flight of stairs, but otherwise hale and hearty. As a rule, however, the tuberculous infection generally follows in time.

* The investigations now in progress under the auspices of the National Tuberculosis Association, in regard to industrial tuberculosis among quarrymen, should constitute a monumental contribution to the subject.

The Specific Influence of Particular Industrial Dusts in Relation to Tuberculosis

It is an interesting and significant fact that in every instance, so far as we are aware, in which a heavy incidence of tuberculosis has been clearly shown to result from exposure to industrial dust, the dust in question has been in part, at least, made up of crystalline rock. It is silicosis which lies at the base of miners' phthisis and which is probably the chief factor in the tuberculosis among axe grinders, although, in grinding and polishing, steel dust may, and probably does, play a part as well. No such striking statistical results as those cited for mining, quarrying and grinding, and pottery making have yet been presented for industries where crystalline rock particles are not involved.

In the case of certain industries we have ample evidence to show that the presence of dust in the lung tissues, and even the development of marked fibrosis, do not tend to predispose to tuberculous infection. Exposure to lime and cement dust, for example, as shown by Dr. George E. Tucker in California, and by recent work in Japan (12), appears not to be associated with high tuberculosis rates. The clearest and most striking case, however, is that of coal dust, which, if it has any effect, appears to exert a protective influence against the invasion of the tubercle bacillus. A clearly marked fibrosis (anthracosis) follows the inhalation of coal dust, and this condition appears to

favor a high mortality from acute respiratory disease; but the tuberculosis death rate among coal miners is uniformly and characteristically low. The figures presented in Table 7 from Hoffman's study (2) bring out the typical relation with great clearness.

The occupational statistics presented by the Registrar-General of Great Britain include a particularly striking comparison between coal miners and tin miners, the former exposed to coal dust, the latter to hard crystalline dust. The comparative mortality figures for tuberculosis in 1900–1902 were 186 for all occupied males, 85 for coal miners and 838 for tin miners.

TABLE 7. — MORTALITY IN COAL MINING DISTRICTS OF PENNSYLVANIA

District	Deaths per 100,000		
	Pulmonary Tuberculosis	Other Forms of Tuberculosis	Other Respiratory Diseases
Scranton	79.9	16.6	261.2
Wilkes-Barre	74.9	19.4	212.5
Remainder of state	110.5	16.4	184.2

The reason for this extraordinary difference between the effects of different dusts is still largely a matter of speculation. It may be due to the physical character of the dust — the kinds that do not predispose to tuberculosis being generally softer and amorphous in structure, the kinds that do predispose being generally hard and crystalline or acicular — or there may be specific chemical influences at work, as seems particularly probable in the case of coal. Dr. Oskar Klotz in a valuable contribution on *Pulmonary Anthracosis — A Community Disease* (13) suggests that "carbon deposits by inducing fibrosis tend to encapsulate chronic tuberculous foci." We are left at a loss, however, to explain why the fibrosis clearly induced by siliceous dust does not exert a similar protective influence.

The most recent study of the difference between these specific effects of various dusts is a communication by Mavrogordato from Dr. Haldane's laboratory (14). Mavrogordato believes that coal and shale dusts on entering the lung tissue set up a vigorous catarrhal reaction which leads to their elimination, while siliceous dust is retained. He even suggests the possibility of securing protection against siliceous dust by mixing with it a certain amount of coal dust which will stimulate the elimination of both together. He admits, however, that an overdose of even coal dust may produce harmful effects.

It is perhaps safest to leave the question an open one for the present. It is clear that the dusts to which workers are exposed in metal mining, quarrying and grinding, strongly predispose to tuberculosis, and that the dusts produced in coal mining and cement working do not. The conclusive explanation of these facts remains for the investigator of the future.

With regard to a great intermediate group of other industries which have commonly been classed as dusty trades, we are inclined to await further and better statistical evidence before reaching a final conclusion as to the existence of what can fairly be called industrial tuberculosis. Mr. Hoffman believes, and most of the textbooks teach, that not only the iron and steel industry as a whole, the jewelry industry, and the printers' trades, but even many industries involving a relatively slight exposure to organic dust — such as boot and shoe making, the textile industry, and the like — are exposed to the hazard of industrial tuberculosis. For reasons cited in the previous section, we are inclined to regard these conclusions with a certain amount of scepticism. As indicated by the comparisons quoted in Table 1, it is evident that industrial workers, as represented by industrial policy-holders, show a ratio of tuberculosis deaths to total deaths dis-

tinctly higher than that characteristic of the general population. This higher ratio, even if it indicates a higher rate, may well be due to general social and economic conditions associated with the wage-earning life, and not directly to the conditions in the workshop itself. That it is the result of a dust hazard in such employments as the textile industry or the iron and steel industry, there is not the slightest reason to affirm.

We shall make progress most surely if we draw definite conclusions as to the existence of a real industrial tuberculosis only where intensive studies have shown a markedly excessive death *rate* from tuberculosis, as compared with population groups of similar social and economic status and racial composition. Evidence of this kind is available at hand chiefly, if not solely, for industries like metal mining, quarrying, pottery making and grinding, which involve exposure to large amounts of hard, crystalline inorganic dust.

(*To be continued*)

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ESTIMATION OF TOXIC WATER SOLUBLE DUST WITH THE PALMER APPARATUS*

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DURING the carrying out of tests for the determination of aniline vapors in the air, the question arose as to the possibility of finding aniline attached to the particles of dust formed in those branches of the industry which were dusty and in which aniline was one of the products or by-products. With this in view, tests were run to determine (*a*) the presence of aniline in the dust, (*b*) the total solid count, and (*c*) the number of dust particles.

These tests were conducted in front of the stills in the aniline plant while the iron oxide was being emptied out, the dust in this case being iron oxide, and in the indigo house in front of the vacuum driers when they were being emptied of phenylglycine and when the phenylglycine was being screened, the dust in this case being phenylglycine. In connection with both of these processes there is found a great amount of dust. Details of the processes are given in a previous article on the *Determination of Aniline Vapors in the Air* (1).

Method of Carrying Out Tests

In making the three determinations — namely, the aniline content of the dust, the total solids in the air, and the dust particle count and determination — the Palmer dust collecting apparatus was employed. For details as to the working of the apparatus, the reader is referred to Dr. Palmer's (2) article in the American Journal of Public Health. This apparatus was set up at the level of the worker's mouth and at the same distance from the machinery as that at which the worker stood. With the exception of the medium used for entraining the samples, all samples were collected in the same way. The determinations were made as follows:

A. Quantitative Determination of the Presence of Aniline in the Dust. — The medium used here was an approximately 10 per cent. solution of hydrochloric acid, a medium in which aniline is soluble and in which is formed an aniline hydrochloride. The samples were then titrated for aniline, using the sodium nitrite method of titrating as described under method II of my article on the *Determination of Aniline Vapors in the Air.*

B. Determination of Total Solids in a Definite Volume of the Air. — The medium here used was distilled water, though in this medium the phenylglycine was partially soluble. In determining the amount of total solids in the samples, they were first dried over a water bath in a porcelain dish, the weight of which had previously been determined, and then placed in an electric oven and dried to a constant weight. The difference between the weight of the dish and the final weight gave the weight of the solids in the sample.

C. Determination of the Total Dust Count. — The medium here used was liquid paraffin oil, since iron oxide and phenylglycine are not soluble in this oil. The determinations of the count were made by the method of Palmer, Coleman and Ward (3) as modified by Dr. Smyth (4).

Results of Tests

A. Table 1 summarizes briefly the results of the determinations of aniline attached to dust particles. As may be seen from this table, tests for aniline attached to

* Received for publication June 15, 1920.

TABLE 1. — QUANTITATIVE DETERMINATION OF ANILINE ATTACHED TO DUST

No. of Sample	Phase of Process	Duration of Process in Minutes	Collecting Apparatus	Medium Used	Amt. Aniline in 1 Cubic Meter	Amt. Sample Collected in Liters	Amt. of Aniline in Sample	Amt. Aniline Worker Inhales in Process
1	emptying still of iron oxide	20	Palmer dust collector	10% HCl	0.0636 gm.	566	0.036058 gm.	0.0108156 gm.
2	emptying still of iron oxide	20	Palmer dust collector	10% HCl	0.0780 gm.	566	0.044194 gm.	0.013254 gm.
3	emptying still of iron oxide	10	Palmer dust collector	10% HCl	0.0465 gm.	425	0.019768 gm.	0.059306 gm.

the dust were made in the aniline plant by the Palmer apparatus, the medium employed for getting the aniline in solution being a 10 per cent. solution of hydrochloric acid. The samples collected were titrated for aniline by means of the sodium nitrite test as described under method II of my previous paper (1).

B. The results of the determination of the total solids in the samples of air taken are briefly summarized in Table 2. These results show that the air, as regards total solids, had 1.4–2.7 gm. per 100 cubic feet, an amount greater than any recorded by Dr. Smyth and Dr. Miller in their article on *The Dust Hazard in Certain Industries* (5).

C. The tests upon the samples collected for the purpose of determining the number of dust particles per cubic feet are given in Table 3. These tests show a very high dust count. The difference between the counts of particles in the water medium and of particles in the liquid paraffin shows the value of the Palmer apparatus when a dust is being collected that is soluble in distilled water, for into this apparatus can be put different media, the medium in each case being chosen according to the character of the sample to be collected.

A microscopic study of the particles entrained in the medium showed that most of the particles in the samples collected while the iron oxide was being dumped from the driers, were dark brown with irregular jagged edges, which is characteristic of iron oxide, a metallic dust. The samples from the indigo plant showed fields of tiny, spherical, light brown, glistening particles, such as are characteristic of phenylglycine.

Significance of the Foregoing Results

1. As regards the presence of aniline attached to the particles of dust:

(*a*) The tests made at the stills showed a small amount of aniline attached to the

TABLE 2. — DETERMINATION OF TOTAL SOLIDS IN AIR SAMPLES

No. of Sample	Phase of Process	Apparatus Used	Length of Time Run	Amt. Collected	Total Solids in Sample	Total Solids in 1 Cu. Ft. Air	Total Solids in 100 Cu. Ft. Air
1	emptying phenylglycine from driers.....	Palmer dust collector	10 min. at 2½ cu. ft. per minute	25 cu. ft.	0.6751 gm.	0.0270 gm.	2.7 gm.
2	emptying phenylglycine from driers.....	Palmer dust collector	15 min. at 2½ cu. ft. per minute	30 cu. ft.	0.4200 gm.	0.0140 gm.	1.4 gm.

particles of iron oxide. Had similar tests been made for aniline attached to dust particles in the indigo house, we would doubtless have found a high aniline count, for the tests for free aniline in the air of the indigo plant showed a high aniline content (1).

The fact that aniline is present in such high quantity doubtless accounts for the illness of the workers connected with this phase of the process, since, as Lehmann (6) and Miller and Smyth (5) show, a worker may retain in his lungs one-third of the total solid material inhaled. The aniline present in the particles of dust retained finds its way into the worker's system and, unless it is eliminated, accumulates and produces a toxic effect on the blood. In considering the toxic effect of aniline, the entire amount retained in the body in both the respiratory and gastro-intestinal tracts must be taken into consideration.

(*b*) The efficiency of the Palmer dust collecting apparatus in entraining all the aniline attached to the particles of dust cannot be definitely stated. The apparatus is, however, efficient to the extent that it entrained a sufficient amount of aniline to give a positive aniline test in an atmosphere, which, when tested for free aniline, showed 0.04 gm. per cubic feet.

2. As regards total solids and the number of dust particles:

(*a*) The total solids determinations showed 1.4–2.7 gm. per 100 cubic feet, a weight greater than any recorded by Dr. Smyth and Dr. Miller in their article on *The Dust Hazard in Certain Industries* (5).

TABLE 3. — NUMBER OF DUST PARTICLES IN A DEFINITE VOLUME OF AIR

No. of Sample	Phase of Process	Apparatus Used	Length of Time Run	No. Cubic Feet Air Drawn Through	No. Particles per Cubic Feet	Medium Used	Particles (Average of 10 Fields): Relative Distribution According to Size	
							0.001–0.01 mm.	0.01–0.04 mm.
1	emptying still of iron oxide	Palmer dust collector	5 min. at 3 cu. ft. per minute	15	5,000,000	water	176	15
2	emptying still of iron oxide	Palmer dust collector	5 min. at 3 cu. ft. per minute	15	4,500,000	water	150	10
3	emptying drier of phenylglycine	Palmer dust collector	10 min. at 2½ cu. ft. per minute	25	1,184,000	liquid paraffin	71	3
3	emptying drier of phenylglycine	Palmer dust collector	10 min. at 2½ cu. ft. per minute	25	656,000	water	30	0
4	emptying drier of phenylglycine	Palmer dust collector	15 min. at 2½ cu. ft. per minute	37.5	1,900,000	liquid paraffin	140	3
4	emptying drier of phenylglycine	Palmer dust collector	15 min. at 2½ cu. ft. per minute	37.5	300,000	water	20	0

(*b*) As far as the number of dust particles present is concerned, the results showed that about 1,000,000 particles were present in 1 cubic foot in the indigo plant and 5,000,000 particles were present in 1 cubic foot in the still room of the aniline plant while the processes were in operation. The high count of dust particles plus the presence of aniline attached to many of the particles indicates clearly the desirability that workers should be protected from inhaling the dust.

Conclusions

The results of tests made for determining quantitatively the presence of aniline attached to dust particles in the air lead to the following conclusions:

1. The Palmer dust collecting apparatus can be used for determining the presence of aniline attached to dust particles in the air by using a medium in which aniline is soluble.

2. The Palmer dust collecting apparatus can be used for determining the count in the air of dust particles which are soluble in distilled water by substituting a medium in which they are not soluble, as for example, paraffin oil.

3. The Palmer dust collecting apparatus can be used for determining total solids in the air.

4. In collecting a sample of aniline from the air, a sufficient amount should be collected to enable the observer to make at least two titrations on each sample. The longer the apparatus is run the more accurate will be the results.

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STUDIES IN INDUSTRIAL PHYSIOLOGY: FATIGUE IN RELATION TO WORKING CAPACITY. I. COMPARISON OF AN EIGHT-HOUR PLANT AND A TEN-HOUR PLANT

A REPLY

The writers of Public Health Service Bulletin No. 106 are indebted to Dr. Drinker for an opportunity. His criticism in the October number of the Journal of Industrial Hygiene calls their attention to the danger that the purpose and nature of their report may be misapprehended. They take, therefore, this occasion to state what in their opinion is the precise value of such a body of facts as is contained in the report under discussion, and what their purpose was in following the manner of presentation adopted.

The study of the human factor in industry has, as is well known, lagged far behind the study of its mechanical agents, of plant, equipment, machinery, etc. Only lately, and especially under pressure of war, has human working capacity begun to claim its arrears of scientific inquiry and investigation. The admirable work of the British Health of Munition Workers' Committee broke ground in a number of directions for such inquiry and study. They performed a signal service in focussing attention upon some of the pressing and unsolved problems of labor — among others on the length of working hours — and they presented valuable evidence on the output of workers operating under different factory schedules. In emphasizing the need of extending such inquiries and increasing their precision, of multiplying exact investigation, lay one of the most valuable contributions of their reports.

The body of fact which was at the disposal of the writers of the American report was the result of an able, exact, and painstaking study. It had been dominated by the spirit and so far as possible pursued by the methods of scientific research. Observations in the field had been conducted with minutely careful accuracy. Every precaution had been taken to reduce the possibility of error, alike of observation and record. Methodologically it represented an appreciable advance in technique over the British reports. It constituted in its strictly limited field the most intensive study of output and accidents yet recorded, so far as known to the writers, for any two factories.

The findings of the investigation at these two plants might indeed have been presented separately without comment and without indication of contrast. But from the mass of data furnished by a scientifically disinterested study, one contrast, when the facts were analysed and sifted, persistently emerged, inevitably challenging attention. The factory running on the eight-hour schedule showed a remarkably steady maintenance of output; the factory running on the ten-hour schedule showed as marked a decline. The eight-hour workers, again, all showed a tendency to work to capacity, the ten-hour workers in many cases deliberately to fix or limit their output. The eight-hour plant records showed almost no loss of time; at the ten-hour plant lost time in beginning and ending work was the rule. At the eight-hour plant accidents varied very nearly with speed of production; at the ten-hour plant a heavier increase of risk seemed to accompany the failure of working capacity. This contrast seemed to the writers highly significant. It indicated to their minds, where other explanations considered failed to cover the case, a certain conclusion as to the efficiency of one schedule over another. Was this contrast to be obscured without hypothesis adopted or conclusion drawn? They accepted frankly the indication of the facts, embodying in each chapter the contrast between the two plants, letting table and chart so far as possible speak for themselves, but giving the gist of the difference by a condensed statement of findings placed at the head of each chapter. These findings, for the convenience of the reader, they reprinted in substance on a single page at the end of the introduction under the inclusive heading, *Relative Efficiency of the Eight-Hour and the Ten-Hour Systems as in Operation at the Two Plants Studied*, and with this reservation they stated the eight-hour system to be the more efficient on the showing of the facts.

While the writers stated conclusions only on the data presented by the study of the two plants, in the text of the report they called attention to the "universal tendency" to which these limited conclusions pointed: that under a shorter schedule human beings work nearer to capacity, and that greater concentration of effort is the unconscious response to shorter

hours. It is needless to say that this relation of higher working capacity to shorter hours is no new discovery. From the classic industrial experiments such as Abbé's down to the studies of the Health of Munition Workers' Committee, it has been an hypothesis constantly and increasingly verified. Dr. Drinker himself accepts it as a commonplace in his reference to "the unconscious speeding up which follows a reduction in hours of work." In referring the specific conclusions on lost time and stereotyping to a general truth, the writers of the bulletin might have called to witness an important body of older industrial experience as well as the pronouncements of the British committee.

Any study of output, however limited, to be fruitful cannot be unrelated to the actual world of industry of which it is a part, and in which the length of working hours has been a subject of speculation for almost a century. Science itself is based on postulates, and isolated unrelated scientific data, fitting into no hypothesis, would be barren indeed, even in laboratory experiment. How much more so in a study of industrial output the object of which is to illuminate larger industrial and social problems, and not only to stimulate research but to lead to experimental action. When the reviewer questions the inferences drawn, is "sceptical" that the difference in working hours accounts for the difference in working capacity between the two factories, he calls salutary attention to the complicated nature of the problem. Clearly the relation of working capacity to length of hours, influenced as it is by a multitude of related factors, cannot be definitely proved by the study of two comparable plants or, indeed, of twenty comparable plants. It could not be proved beyond question even by the study of one single plant running under different schedules of hours. For even within the walls of a single factory at different times variants could not be excluded, as in a chemical analysis, and the conditions of work kept exactly the same. Differences of stock, differences of experience, differences of good or ill-will on the part of the workers, and many other differences might all affect the outcome of the experiment. For definitive proof of hours as the cause of variation, investigation must be multiplied a thousandfold. Approximation to such proof would lie in a volume of investigation, a persistent coincidence among a multitude of variants. Such a volume or such an overwhelming coincidence was obviously not presented in a report the very name of which (*Comparison of an Eight-Hour Plant and a Ten-Hour Plant*) was intended to make clear on the title page the exact scope of the field from which the facts were drawn.

To the reviewer other causes than length of hours appear more likely to be accountable for the difference of working capacity at the two plants — such causes as differences in management and in the constitution of the labor force. That these possible factors were not ignored by the writers, a discussion of these points in the introductory chapter makes clear. They were considered and estimated as being contributory but not the primary cause of the difference between the two plants. While fully granting that we are here in the field of reasoned judgment rather than of complete scientific proof the writers, among several alternatives, held to be primary the one to which in their opinion the weight of evidence inclined.

That the view taken by the Bulletin is the correct one and that the hour schedules are the main differentiating element in the efficiency of the two plants is, in the opinion of the writers, borne out by analysis of the factors involved. Two variants were suggested by Dr. Drinker, each of which he regards as more likely to influence working capacity than length of hours: quality of management and quality of labor. Two indices of working capacity were used in the Bulletin: output and accidents. Taking as possible causes for the contrast in working capacity at the two plants hours, management and quality of labor, it was possible, when considering accidents in the two plants, largely to eliminate management as a variant, and when considering their output largely to eliminate the quality of labor force as a variant. In the case of both output and accidents, the difference in hours persisted as a steady factor in the contrast between the two plants.

Thus, in respect to output, the quality of labor at the two plants may be considered practically on a par. While the eight-hour plant as a whole possesses a more stable body of workers as compared with a more shifting group at the ten-hour plant, it is clear from the report that only piece-rate workers were studied at the latter plant. Since piece rates are paid only to employees who are no longer learners, this is proof to a careful reader that the records of the investigation do not cover work done by the transient or floating type of worker. That such workers are excluded is implicit in the

facts. We might, indeed, have stated further that many of the workers studied at this plant had been at their respective jobs for ten or even fifteen years, and it is quite possible that the average experience of the ten-hour workers was longer than the average experience of the eight-hour workers. In management, however, admitting for the sake of argument that the eight-hour plant is more efficient, this more efficient management may indeed hold the eight-hour workers more strictly to their tasks. Yet, on the other hand, at the ten-hour plant where piece wages are paid, in contrast to the time wages paid at the eight-hour plant, self-interest, even under less efficient management, should tend to keep the workers up to capacity. It is in the face of their own self-interest that these workers work below capacity. The ten-hour plant ranks too high, moreover, in general managerial efficiency for us to refer the whole contrast to slacker management.

In respect to accidents, the quality of the management at the two plants may be considered practically identical. Both factories rank high in the safety-first movement and take every precaution to lower accidents to a minimum. The heavier increase of risk at the ten-hour plant might naturally, then, at first glance be associated with the larger body of inexperience, since the accident records studied covered the entire labor force. The statement in the text, however (p. 130), that the inexperience raises the level but does not change the general character of the accident curve, rests on good evidence, corroborated by Bulletin 234 of the United States Bureau of Labor Statistics (Table 63). The presence of inexperience is not, then, sufficient to account for the greater rise of accident risk at the ten-hour plant.

Thus, when we eliminate the variant of labor, we find differing management insufficient to explain our contrast in working capacity as tested by output. When we eliminate the variant of management, we find a differing labor force insufficient to explain our contrast in working capacity as tested by accidents. For the major factor of the contrast we are brought back to the differentiating element steadily present in our study, the length of hours.

Doubtless besides the three causes under discussion other causal elements were present in the problem, elements which may be of greater or less contributory influence. To make a full appraisal of all these — wages, product, climate, sex, living conditions, etc. — should be a matter of years of research. All these elements must be studied before industry can be conducted on a right physiological basis. Meantime Bulletin No. 106, as stated in the introduction, was not intended to be "a study *in vacuo*," and "not an academic inquiry." In the field of human productivity final solutions lie far off, but immediate and vital questions may not go unanswered. No more than medical science in the laboratory, can industrial science in the factory or, indeed, any applied science wait always upon ultimate proof. Even the great hypotheses of pure science have not waited for statement till the evidence should be all in; the evidence is even now only in process of accumulation. In default of final statements, experiment and practical action must perforce follow the strong indication of probability. The writers of the Bulletin, on the evidence in hand, stated conclusions as indicated to their minds by the facts, inviting further and more inclusive research to confirm or refute them. The expectation of such future research, "a new era of intensive study," following the more impressionistic era of the past is specifically emphasized in the Bulletin. "If such a study . . . is to be fruitful," said the writers, "it must be pursued as a science; and to such a science the results of the present investigation are offered as a definite if limited contribution."

Among additional points to which Dr. Drinker calls attention is the relation of output to fatigue. The writers of the Bulletin are entirely in accord with him in believing that output data do not justify conclusions relative to fatigue in the narrowly physiological sense. On page 29 of the introductory chapter they sought to make this clear by stating specifically that it is not the crude physiological entity of fatigue — still undefined, as Dr. Drinker says — which explains the fall of the output curves. "It is well recognized that the fall is not due to such fatigue alone. In the great complexity of man's psycho-physical constitution, reacting to the most diverse stimuli, other remoter manifestations of fatigue, psychological and nervous, are operative in contributing to the fall of production." The output data, then, while they cannot be held to measure fatigue in the narrow sense, do indeed justify conclusions relative to fatigue in this larger sense which includes not only the manifestations of physiological fatigue but also remoter psychological reactions. Of these even self-limitation of output may be considered one. For self-limitation, which the

reviewer admits to be "unquestionably protective," where it is not a matter of economic self-protection, can itself be explained as in large part a reaction of a past experience of fatigue.

A word remains to be said about the necessarily non-inclusive character of a bulletin which was designed to be the first of several reports on this investigation. It was obviously not within the province of writers reporting on a special section of an investigation, extended in time and covering a wide field, to deal with all its aspects. That they were well aware of the desirability, emphasized by Dr. Drinker, of including the findings of a medical and sociological study in the present report is clear from pages 23 and 24 of the Bulletin. Here, under *Limitations of the Present Study*, they are at pains to note as a serious incompleteness in the material at hand the lack of precisely such a study as the reviewer indicates, and to point out the need of a "companion investigation" to supplement it, "an investigation of individuals" showing the physiological differences in their reaction to work, "a study initiated today by industrial medicine and nursing and capable of far-reaching development."

Finally, Dr. Drinker's rather sweeping pronouncement as to British and American methods calls for some comment. The American investigators played, he considers, an almost imitative rôle. "It is unfortunate," he writes, "that the Public Health Service investigators worked practically entirely with the methods of the English Health of Munition Workers' Committee, and that the United States is thus unable to contribute to the subject a degree of freshness and originality which its importance demands." We are dealing here with matters of fact not opinion, and we may in reply point out certain facts which may have escaped the attention of the reviewer and which should be set straight.

1. It is obvious that the investigators for the British Health of Munition Workers' Committee conducted practically no actual continuous observation of output in the factory itself. To obtain weekly output the use of factory books is entirely legitimate where the investigator is satisfied that the records are properly kept, but that does not alter the fact that the American data as to hourly output offer a contrast rather than an imitation.

2. The investigators for the British committee give practically no hour-by-hour curves. The only exception occurs in their last memorandum where a few isolated operations are collected for comparisons with an accident curve.

3. The investigators for the British committee made no attempt to distinguish the different types of hour-by-hour curves on different types of work either in relation to output or accidents.

4. The American investigators broke entirely new ground:

a. In using the relative deviation from the best hour as a measure of efficiency in both output and accident curves.

b. In using the accident-output ratio as a measure of accident risk and computing the accident-output ratio as an hourly curve. The new developments in technique are described in the Bulletin.

c. In segregating output curves on operations where output was restricted.

d. In attempting to represent the hourly output curve of a factory as a whole by combining the curves from the different types of work as found there.

e. In definitely trying out the effect on daily and hour-by-hour output of introducing recess periods.

f. In attempting to correlate turnover, absenteeism, and the physiological condition of the workers with certain physical conditions in the different departments of each factory.

These facts must have escaped the reviewer's notice. They show that no basis exists for the statement that rhythm in industry is "the single novel feature of the entire work of the Public Health Service investigation." Without belittling the magnificent work of the British Health of Munition Workers' Committee, it is clear that the American investigators have made a distinct contribution in the development of methods to be pursued hereafter in important and necessarily more extensive studies.

To sum up, then, the value of the report may be said to lie in (1) the volume of authoritative fact presented, (2) the new or revised technique of the investigation, (3) the precision of presentation aimed at, and (4) the stimulus which it in turn, following the British reports, may exert in leading to further exact research into the central and most neglected problem of production, the human factor. — *Josephine Goldmark* and *Mary D. Hopkins.*

BOOK REVIEWS

Fatigue Study. The Elimination of Humanity's Greatest Unnecessary Waste a First Step in Motion Study. By Frank B. Gilbreth, Member of American Society of Mechanical Engineers; Member Franklin Institute; Past Vice-President Society for the Promotion of Engineering Education; Honorary Member Society for the Promotion of Occupational Therapy; and Lillian M. Gilbreth, Ph.D. Second edition, revised. Cloth. Pp. 175 with illustrations and index. New York: The Macmillan Company, 1919.

The second edition of this exposition of the Gilbreth methods for attack upon the problems of working efficiency is practically a reprint of the first, the addition of several new illustrations and a final short chapter summarizing the general progress in fatigue study during the past two years representing the only real alterations. It is, however, particularly valuable to have systematic attention to the fatigue problem from an engineer, since the present attack in this country is largely through the medium of physiologists. In insistence upon the value of rest and economy of effort in work, the Gilbreths are more vigorous than those who have come into such investigation with the purely physiological or psychological point of view.

Manufacturers interested in various types of work chairs and tables designed to reduce fatigue and increase efficiency will find valuable and suggestive illustrations in the book. Indeed, though small, this publication represents the only effort at collection of such devices available in the English language. — *Cecil K. Drinker.*